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MILITARY SPACE OPERATIONS

Shuttle and Satellite Computer Systems Do Not Meet Performance Objectives

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Information Management and
Technology Division

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August 5, 1988

The Honorable Bill Chappell, Jr.
Chairman, Subcommittee on Defense
Committee on Appropriations
House of Representatives

Dear Mr. Chairman:

This report responds to your September 8, 1986, request that we assess computer and communication systems for military space operations, with emphasis on the Air Force's development and acquisition of the Consolidated Space Operations Center near Colorado Springs, Colorado. This facility consists of a satellite operations complex, a shuttle operations complex, a supporting communication system, and a related data system modernization project for the satellite operations facility in Sunnyvale, California. The report contains our observations on the cancellation of the shuttle operations complex, development of new computer and communication systems for both the satellite operations complex and the Sunnyvale facility, and Air Force plans for the long-range satellite control system architecture.

We are sending copies of this report to the Secretary of Defense; the Secretary of the Air Force; the Administrator, National Aeronautics and Space Administration; the Chairmen, House and Senate Committees on Armed Services; Senate Committee on Appropriations; House Committee on Science, Space and Technology; Senate Committee on Commerce, Science, and Transportation; and the Director, Office of Management and Budget.

Sincerely yours,

Ralph V. Carlone

Ralph V. Carlone
Director

Executive Summary

Purpose

Military space operations currently depend on numerous computer and communication systems to maintain satellites in their proper orbits and control the space shuttle. Since 1980 the Department of Defense has been developing a facility, the Consolidated Space Operations Center, that is intended to command and control military space shuttle and satellite operations.

The Subcommittee on Defense, House Committee on Appropriations, has expressed concern over the development and acquisition strategy for the Center. At the request of the Subcommittee Chairman, GAO examined the status, current plans, and supporting studies for the Center and the Air Force's long-range plans for a system architecture to support satellite control.

Background

In order to reduce reliance on the National Aeronautics and Space Administration, Defense in 1979 began developing a control facility for its military shuttle flights. In 1980 Defense decided to also perform satellite control at the same facility. Since 1987, after the shuttle portion was cancelled, the Center's development has focused on satellite control.

The Air Force's satellite control network currently tracks about 55 satellites, which provide critical communication, navigation, surveillance, and weather services. Since 1981, Defense has spent about $1.4 billion to develop a new Consolidated Space Operations Center near Colorado Springs, Colorado, including its computer and communication capabilities, and to upgrade the capabilities of the existing satellite control facility located at Sunnyvale, California.

Results in Brief

Air Force cost and schedule estimates for a fully operational facility at the planned Consolidated Space Operations Center and planned upgrades to the existing satellite control center at Sunnyvale have been more optimistic than events have borne out. Performance problems identified through testing have delayed the transition of these systems to an operational status. The Air Force expects to spend about $1.85 billion, about three times its original estimate, to make the systems operational.

Future plans are ambitious. The Air Force is studying a long-range architectural concept that would alter the overall system network for satellite control operations between 1990 and 2015 in order to make it more efficient and survivable. This concept, if implemented, would

require significant advances in data processing and communication system technologies and performance at an estimated 1985 price tag of $48 billion. During GAO's audit, Defense cancelled development of the shuttle complex near Colorado Springs because it no longer considered it affordable.

Principal Findings

System Delivery Schedules and Costs Exceeded; Performance Objectives Not Met

A 1981 Air Force plan estimated that the redesigned computer system for satellite operations would be operational at Sunnyvale in 1984 and at Colorado Springs in 1985. In January 1987 the Air Force reported to the Congress that the computer system would not be declared fully operational at Sunnyvale until September 1987. This system was also scheduled to begin actual control operations at Colorado Springs by December 31, 1987. The Center's first satellite control complex is now scheduled to be operational in late 1988. The Sunnyvale facility commander estimates that full operational capability at that facility may not be achieved until late 1989.

Cost estimates have risen. In 1980, an Air Force plan estimated the cost for new satellite control capabilities at Sunnyvale and Colorado Springs at about $600 million. The Air Force spent $1.4 billion through fiscal year 1987 for these capabilities, and projects spending about $450 million more to make the Center at Colorado Springs fully operational.

The redesigned computer system has had continued difficulty processing data simultaneously from several satellites and processing the amount of data from each satellite needed by users. In February 1987, the system was averaging a 69.5 percent success rate in performing satellite contact functions; the minimum requirement is 95 percent. In response to a draft of this report, Defense reported in May 1988 that the success rate had increased to 90 percent. GAO has not evaluated the comparability or accuracy of this measurement.

As of October 1987, performance projections indicated that the computer would require 112 percent of available capacity. The Air Force originally required that the computer use no more than 50 percent of its capacity (retaining room for anticipated growth), but this requirement has been relaxed. The Air Force is now considering accepting a system

using up to 100 percent of capacity, leaving little or no room for anticipated work load growth.

Air Force determined that the original system controlling communications between the Center and satellites would not work effectively. Because of this, the Air Force decided instead to use another communication system. However, this new system also has problems that may reduce or delay operational capabilities. The system as currently configured will communicate 1 million bits of data per second instead of the originally planned 5 million; and the Center will be required to communicate with satellites through Sunnyvale until at least 1989. Defense considers Sunnyvale to be vulnerable to failures resulting from earthquakes and other threats such as a direct enemy attack. If an earthquake or other occurrence should render Sunnyvale inoperable during this time, Defense's ability to communicate with its satellites could be impaired.

Long-Range Study Envisions More Survivability, Significant Investment

Future satellite control operations will require improved survivability plus increased capacity and efficiency, according to a 1987 Air Force study, which projects 150 satellites on-orbit by 2015—not including the nearly 10,000 that may be needed for a strategic defense system. The Air Force plan proposes using complex computer and communications technologies in new ways—at an estimated cost of $48 billion.

The new architecture would require more computer processing of data on-board the satellites to reduce reliance on ground facilities. It would also use space-based communications and tracking satellites. An assessment of the technical risks shows that the Air Force would face a number of complicated technological challenges, including those related to expert systems (those performing at human levels) and the development of decision-making software. If implementation of such a system is to succeed, significant advances in performance are essential. GAO believes it is important that the strategy for carrying out satellite control be given attention and visibility in order to help assure that a clear and comprehensive plan is developed.

As development in computer technology and communications for controlling satellites reaches into the next century, as costs continue to grow and as this country's defenses become more intertwined with this advancing technology, it becomes even more critical that decision makers have a high degree of confidence that projected capabilities can be met and are affordable. Accordingly, GAO believes it is important that

the strategy for carrying out satellite control be given sufficient attention and visibility in order to help assure that a clear, cohesive, and comprehensive plan is developed, specifying long-range goals, objectives, capabilities, technical challenges, and the estimated cost to carry out Defense's satellite control mission.

Defense Cancelled Air Force's Shuttle Complex

Despite original plans for a full shuttle complex at Colorado Springs to match the capabilities of the National Aeronautics and Space Administration's Johnson Space Center, the Air Force, while preparing its fiscal year 1987 budget, eliminated funding for the shuttle complex on the grounds that the estimated $600-million cost was too high. Defense later reinstated funding for a limited, "austere" shuttle complex. In November 1986, prompted by a $29-million congressional budget reduction for the Consolidated Space Operations Center, Defense eliminated funding for its shuttle complex. Through fiscal year 1987 the Air Force has spent $78.5 million developing the shuttle complex and estimated that an additional $103 million would have been used to complete development by 1992.

The austere shuttle complex, if its funding had continued, would not, however, have satisfied the original requirements justifying an independent military shuttle complex. While it would have provided some improvements, it would not have eliminated Air Force's reliance on the Johnson Space Center for some critical functions.

Recommendations

GAO is not making any recommendations.

Agency Comments

The Department of Defense generally agreed with GAO's findings, but Defense stated that there were reasons other than cost for cancelling the shuttle complex. GAO agrees that there were reasons besides cost, but the ultimate decision to cancel was based on budget reductions. At the conclusion of each chapter is a detailed evaluation of the comments provided by the Department of Defense (see pp. 11, 16, 24, and 29). The National Aeronautics and Space Administration provided official oral comments, which resulted in some minor changes in chapter 2.

Contents

Appendixes

Abbreviations

CSOC	Consolidated Space Operations Center
DOD	Department of Defense
GAO	General Accounting Office
IBM	International Business Machines Corporation
IMTEC	Information Management and Technology Division
MASAD	Mission Analysis and Systems Acquisition Division
NASA	National Aeronautics and Space Administration
NSIAD	National Security and International Affairs Division

Introduction

Background

The Air Force is developing the Consolidated Space Operations Center (CSOC) as part of its ongoing effort to expand and improve Department of Defense's (DOD's) capabilities for military operations in space. The CSOC facility is located at Falcon Air Force Station near Colorado Springs, Colorado, and is part of the Air Force Satellite Control Network.

CSOC was originally designed to control both military satellites and military space shuttle missions. Its shuttle operations complex would have provided command and control for DOD space shuttle missions, in conjunction with the National Aeronautics and Space Administration's (NASA's) Lyndon B. Johnson Space Center in Houston, Texas. Funding for the shuttle complex was not included in the fiscal year 1988 budget, and the contract to develop its data processing system was terminated at the end of fiscal year 1987. Thus, CSOC's primary responsibility will be the command and control of military satellites.

Currently, the Air Force's primary satellite operations facility is located in Sunnyvale, California. Originally, Sunnyvale and CSOC were to function as mutual backup systems to command and control DOD satellites in the event of failure of either facility.

DOD considers Sunnyvale to be vulnerable to failures resulting from earthquakes and other threats such as a direct enemy attack. The CSOC satellite control complex and communication system will provide additional capacity and some backup to the Sunnyvale facility. Satellite control officials said that mobile satellite control centers and other facilities are planned to also provide backup capability in the event of failures at either Sunnyvale or Colorado Springs.

Sunnyvale and CSOC will use virtually identical new computer systems to launch, operate, and maintain DOD communication, navigation, weather, and surveillance satellites. Since 1981 the Department of Defense has spent about $1.4 billion to develop a new Consolidated Space Operations Center near Colorado Springs, Colorado, including its computer and communication capabilities, and to upgrade the capabilities of the existing satellite control facility located in Sunnyvale, California. DOD estimates it will spend approximately $477 million to develop and acquire the new computer system for the Sunnyvale facility, approximately $904 million on CSOC through fiscal year 1987, and $449 million thereafter, to completely develop and implement the capabilities at the CSOC facility.

Agencies Responsible for Developing and Operating CSOC

The Air Force Systems Command is the procuring agent for CSOC. The Air Force Space Division of Systems Command is responsible for directly managing the CSOC program acquisition, including the new computer system for satellite control operations to be used by both Sunnyvale and CSOC. The Air Force Space Command, through its Second Space Wing at Falcon Air Force Station, is the operator of CSOC, and has participated in planning and defining CSOC requirements.

NASA's Johnson Space Center worked with the CSOC Systems Program Office at the Air Force Space Division in design and development of the shuttle complex. The Air Staff at Air Force Headquarters and the Office of the Secretary of Defense, both located in Washington, D.C., provided overall policy direction and budgetary guidance. The Air Force Operational Test and Evaluation Center will plan and conduct tests of CSOC systems to determine how well the operational requirements for the systems are being met, and the systems' readiness for operations.

Previous Concerns About the CSOC Program

In response to prior congressional concerns, we issued two reports on the CSOC program. Our 1982 report[1] found in part that (1) the Air Force was following vague policy guidance and a hastily implemented developmental approach for CSOC to meet only short-term objectives, and (2) the CSOC development program could be subject to cost overruns, schedule slips, and an inability to provide the required operational capabilities.

Our 1983 report[2] stated that (1) the original DOD justifications for the shuttle complex were questionable, and (2) the Air Force should defer implementation of the shuttle complex until NASA and DOD identify the systems configuration needed to support a fully operational shuttle system, including DOD's plans for military use of the shuttle.

Objectives, Scope, and Methodology

We initiated our work in response to a September 8, 1986, request from the Chairman, Subcommittee on Defense, Committee on Appropriations, House of Representatives. In subsequent discussions with the Chairman's office, we agreed to review current CSOC plans and supporting

[1]Consolidated Space Operations Center Lacks Adequate DOD Planning (MASAD-82-14, Jan. 29, 1982).

[2]Implications Of Joint NASA/DOD Participation In Space Shuttle Operations (NSIAD-84-13, Nov. 7, 1983).

studies in order to address (1) the ability of an "austere" shuttle complex and satellite operations complex to fulfill defense and intelligence space mission needs, (2) CSOC's ability to accommodate future needs and policy options, (3) the technical risks in the CSOC development program, and (4) the costs and affordability of CSOC.

In April 1987, we briefed the Subcommittee staff on the results of our work. On the basis of that briefing and other arrangements with the Chairman's office, we agreed to (1) update our results by addressing DOD's cancellation of the shuttle complex and the status of DOD's computer and communication acquisitions that will support satellite operations, and (2) obtain and provide information on an Air Force long-range plan for the satellite control system architecture. This plan was provided to us while we were examining CSOC's ability to accommodate future needs and policy options. The plan evaluates various satellite control architectures, of which CSOC would be one element.

To evaluate the ability of CSOC to fulfill space mission needs and to assess the technical risk of the development program, we analyzed contractual system performance requirements, prior studies of mission needs, system performance test results, minutes from technical design meetings, and studied plans and schedules. To evaluate CSOC's cost and affordability, we collected and analyzed cost records, program management directives, budget and contract justifications, and contract documentation. We addressed the future adequacy of the CSOC program by collecting and analyzing information on the short- and long-range plans for CSOC, as well as the overall Air Force Satellite Control Network.

We interviewed DOD, Air Force, and NASA officials and contractor personnel who were responsible for, or involved in, the development and operation of CSOC, the data system modernization program at Air Force's Satellite Control Facility, shuttle operations at Johnson Space Center, and the Air Force Satellite Control Network. We reviewed and analyzed documents related to (1) the CSOC program, (2) the data system modernization program, (3) operation of CSOC by Space Command, (4) space shuttle planning, training, and mission operations at Johnson Space Center, (5) the Air Force Satellite Control Network, and (6) national space policies. We also reviewed previous GAO reports on the CSOC program.

Our work was performed at (1) the Office of the Secretary of Defense in Washington, D.C., (2) Air Force Headquarters, in Washington, D.C., (3) Air Force Systems Command headquarters at Andrews Air Force Base

in Camp Springs, Maryland, (4) Air Force Systems Command's Space Division at the Los Angeles Air Force Station, California, (5) Air Force Space Division's Shuttle Operations and Planning Complex Project Office in Houston, Texas, (6) Air Force's Consolidated Space Test Center (formerly the Satellite Control Facility) at Onizuka Air Force Station in Sunnyvale, California, (7) NASA's Johnson Space Center in Houston, Texas, (8) Air Force Space Command in Colorado Springs, Colorado, (9) the CSOC facility at Falcon Air Force Station near Colorado Springs, Colorado, (10) the Air Force Operational Test and Evaluation Center's detachments at CSOC and the Consolidated Space Test Center, (11) the Aerospace Corporation in El Segundo, California, and (12) the International Business Machines Corporation (IBM) in Gaithersburg, Maryland.

During our review, we obtained the views of responsible DOD and NASA program representatives and have included their comments in the report where appropriate. We received official written comments on a draft of this report from DOD, which are included as appendix 2, and official oral comments from NASA. These comments are addressed, where appropriate, throughout the report.

Our audit work covered the period between September 1986 and October 1987 with some updating work performed during January and February 1988. We performed our work in accordance with generally accepted government auditing standards.

Agency Comments and Our Evaluation

DOD disagreed with including the full cost of developing the new satellite control computer system ($477 million) for the Sunnyvale facility, with the cost of developing CSOC through fiscal year 1987 ($904 million) to arrive at a total cost of $1.4 billion (see appendix II). We recognize that these are two separate development efforts. Since the new computer system is needed for satellite control at CSOC, we do not consider it inappropriate to separately identify these development costs and combine them in our report. In addition, it should be recognized that the successful implementation of CSOC is highly dependent on the successful development and implementation of the new computer system.

DOD's Shuttle Complex Has Been Cancelled

DOD cancelled development of CSOC's shuttle complex during formulation of the fiscal year 1988 budget because the complex was not considered affordable. Additionally, we found that NASA's Johnson Space Center projects it can support all currently planned DOD missions through the early 1990s; the planned shuttle complex would not have satisfied original requirements; and a recently announced DOD space policy, calling for active exploration of the potential use of military man-in-space, may change space operations requirements.

DOD's Shuttle Complex: An Overview

In 1979, DOD justified the development of an independent military shuttle complex based on the need to correct several deficiencies in its ability to plan and execute space shuttle flights at NASA's Johnson Space Center. Specifically, according to DOD, its own complex was needed because Johnson Space Center:

- was the sole facility that could prepare for and control shuttle flights (that is, a single point of failure) and was vulnerable to natural and enemy threats,
- lacked sufficient capacity to support the planned number of DOD classified shuttle flights,
- could not conduct shuttle operations above the secret security level, and
- could not provide DOD with the desired degree of control over military shuttle operations.

In 1982, NASA and the Air Force began to design the computer system for an independent DOD shuttle complex. To be independent of Johnson, the computer system would need to perform three key functions: flight planning, flight readiness, and flight control. Flight planning operations produce the flight trajectories and schedules for crew and mission activities. Flight readiness operations produce the computer software necessary for each mission, modify the mission control systems, and support flight and ground crew training for each flight through computer simulation. Flight control uses the mission control system to perform command and control of each shuttle flight from launch through landing.

These functions currently are conducted at the Johnson Space Center using numerous computers and over 8 million lines of software code written in a variety of computer languages. DOD planned to replicate over 90 percent of this software for use at its shuttle complex.

DOD Cancelled Its Shuttle Complex

In August 1985, the Air Force cancelled all funding for the shuttle complex because the estimated development cost of about $600 million was considered too expensive. However, 2 months later, in October 1985, DOD reinstated limited funding to develop an austere shuttle complex. The austere complex was to essentially replicate the Johnson Space Center functions that were considered to have the highest priority by Air Force and NASA.

In June 1986, the Air Force awarded a contract to IBM to develop and acquire the computer systems for an austere shuttle complex. This was approximately 6 months after the January 28, 1986, loss of the space shuttle Challenger. IBM was to provide a limited shuttle complex with most, but not all, of the flight planning capability by 1989 and a flight control capability by 1991. The contract included options to provide a full shuttle complex, including all flight readiness functions, by the mid-1990s.

In November 1986, funding for the austere shuttle complex was cancelled. This cancellation was prompted by a congressional budget reduction to the CSOC program of approximately $29 million. According to DOD officials, the shuttle complex was not affordable when compared to higher priorities. An April 1987 Air Force estimate shows that about $78.5 million will have been spent on the shuttle complex development by the end of fiscal year 1987, including all prior design and study activities. The Air Force also estimated that the austere shuttle complex would have cost an additional $103 million to complete development by fiscal year 1992, or an additional $383 million to complete development of a full facility by the mid-1990s. Although the shuttle complex was cancelled, the Air Force continued the IBM development contract through the end of fiscal year 1987 to allow the contractor time to fully document those design and development activities that it had conducted.

Johnson Space Center Projects It Can Support Currently Planned DOD Mission Requirements

Prior to the Challenger accident, the Air Force did not consider the Johnson Space Center to have sufficient capacity to support the number of classified shuttle flights being planned by DOD during the 1990s. However, the Center has reported that it can support the reduced flight rate currently projected through the early 1990s. Since the accident, DOD has shifted many of its missions to expendable launch vehicles. The Johnson Space Center is also considering changes in the design of its computer systems that would allow it to increase its mission capacity.

With the shuttle designated as DOD's primary launch vehicle, the Air Force did not consider the Johnson Space Center to have sufficient capacity to support the 10 to 12 classified DOD shuttle flights per year being planned for the 1990s. In October 1985, the Air Force estimated that Johnson would be able to support six to eight classified shuttle flights per year for an interim period until the Shuttle Operations Complex was activated. However, after the Challenger accident, a revised shuttle flight schedule was issued in October 1986 that showed no more than six flights per year for DOD.

By October 1986, DOD reduced its shuttle launch requirements and had begun to acquire additional expendable launch vehicles. For example, the Air Force changed its procurement plans for Titan IV expendable launch vehicles from 10, before the Challenger accident, to 23. In February 1987, DOD issued a space policy that stated, "Unmanned vehicles will be the primary launch vehicles for national security payloads not requiring a manned presence in space."

The Johnson Space Center's support to DOD would be provided with that Center's current computer systems and previously planned upgrades.[1] For example, according to Johnson officials, flight software production and ascent/descent flight design systems can currently support up to five secure flights annually. While this capacity allows Johnson to support all approved and projected military flights through 1991, upgrades to both systems are necessary to support the six military flights per year projected for 1992-1994. The officials told us that these upgrades would have been necessary, even if DOD had not cancelled its shuttle complex. These officials said the upgrades can be completed by 1990 and will make it possible to support a military flight rate of at least 10 per year. In addition, Johnson Space Center officials are studying alternative architectures for the computer system supporting shuttle mission operations.

DOD's Austere Shuttle Complex Would Not Have Satisfied Original Requirements

DOD's austere shuttle complex would not have satisfied the original requirements justifying an independent military shuttle complex. For example, the complex would not have:

- eliminated Johnson Space Center as the single point of failure,
- increased overall flight rate capacity,

[1]Space Operations: NASA's Use of Information Technology (GAO/IMTEC-87-20, Apr. 17, 1987).

- eliminated all critical constraints for conducting missions above the secret security level, or
- provided DOD complete operational control over shuttle missions.

Although the complex would have provided some improvements, the Air Force would have still been dependent on Johnson Space Center for certain critical functions. For example, though the austere shuttle complex would have provided additional flight planning and control, it would not have had the ability to simulate new ascent/descent phases of a flight or produce the specific flight software. The Center's flight rate capacity for these functions would have remained a constraint on DOD. Consequently, a failure at the Johnson Space Center could have stopped or seriously delayed any planned DOD mission.

DOD's ability to conduct missions above the secret security level and to increase its operational control over shuttle missions at the austere shuttle complex would have also been constrained because of its dependence on Johnson Space Center. Dependence on the Johnson Space Center to perform the above critical functions would have exposed sensitive mission data to additional risk of compromise since none of its systems are certified above the secret security level. CSOC program officials stated that alternative procedures, although inefficient, can be developed to adequately protect this data. In addition, DOD's operational control over shuttle missions would not have improved. According to an Air Force shuttle flight director and Johnson Space Center officials, NASA would not relinquish complete control to DOD because NASA views the safety of the shuttle and crew as strictly its responsibility.

DOD's Space Operations Requirements May Change

DOD's most recent space policy, dated February 1987, provides direction to actively explore the potential use of military man-in-space. The policy states that DOD:

"will ensure that the unique capabilities that can be derived from the presence of military man-in-space shall be utilized to the extent feasible to perform in-space research and development, and to enhance existing and future missions in the interest of national security."

The DOD authorization law for fiscal years 1988 and 1989, approved December 4, 1987, directs the Secretary of Defense to study the need for a centralized facility to conduct both manned and unmanned space operations. The Secretary is required to submit a report to the Senate and House Armed Services Committees.

DOD briefings addressing this recent space policy indicated that DOD may identify a long-term need for complex and highly classified missions, involving not only the shuttle but other future space vehicles. It is unclear whether this need may justify a shuttle complex at CSOC. Since CSOC's shuttle systems were to have essentially replicated Johnson Space Center's systems, and these were not designed to support such complex missions, DOD will likely consider other system design alternatives if a future determination is made that a separate CSOC shuttle complex is needed.

Agency Comments and Our Evaluation

In commenting on a draft of this report, DOD states that there were reasons other than the $29 million congressional budget reduction that caused it to cancel development of CSOC's shuttle complex (see appendix II). We agree that there were factors other than the reduction that supported the decision. However, the Program Budget Decision memorandum that deleted out-year funding for the shuttle complex clearly identifies the budget reduction as a primary factor in the cancellation decision. Specifically, DOD believed that the shuttle complex was still needed, but was not affordable. The Air Force had awarded the development contract for the complex almost 6 months after the Challenger accident and DOD waited until after the congressional budget reduction — almost a year after the accident — before cancelling the shuttle complex. Accordingly, we believe that the conclusion that the reduction prompted the cancellation is valid.

New Computer and Communication Systems for Satellite Control Are Not Operational and May Require Additional Investment

The Air Force's capability to plan and control satellite operations will depend upon, among other factors, the performance of its new computer and communication systems. As of October 1987, initial operational testing had not been completed, several technical performance issues remained unresolved, and additional investments may be required. For example:

- the computer system for CSOC's first mission control center had difficulty reliably maintaining contact with the satellites with a success rate ranging from 35 percent to 84 percent, when 95 percent is the minimum requirement;
- supporting the expected work load may require more capacity than the computer offers;
- the Air Force had to revise its initially-planned CSOC communication link to the satellites to overcome technical problems. The currently planned architecture will not be available until at least 1989 and will provide about 1 million bits of data per second versus 5 million bits of data per second as originally planned; and
- although the Air Force plan expected the new satellite control capabilities, including these systems, to be operational at an approximate cost of $600 million, the Air Force will have spent about $1.4 billion through fiscal year 1987 at CSOC and Sunnyvale and expects program completion and transition to operations at CSOC to cost $449 million more. In addition, the Air Force plans to spend approximately $1.8 billion during fiscal years 1987 through 1992 to continue modernizing satellite control systems.

Satellite Control Operations: An Overview

The Air Force operates a satellite control network that currently controls operations of approximately 55 on-orbit satellites that provide critical defense communication, navigation, surveillance, and weather services. This network consists primarily of worldwide, fixed, ground-based, tracking stations; a central control facility at Sunnyvale; and communication links connecting these components. The Sunnyvale facility consists of individual satellite mission control centers, each of which controls a specific type and number of satellites. Currently, over 4,000 government and contract staff operate this network.

Personnel at these facilities use computer and communication systems to plan and control satellite operations. For example, computer systems receive the satellite telemetry data via communication links, process the data for such operations as determining orbital correction instructions,

and then transmit commands back to the satellite via communication links.

In 1980, the Air Force issued a plan to improve the overall satellite control network, which would involve development of an additional satellite control facility at CSOC. CSOC was to provide the additional capacity to support the expected increase in satellites and continue satellite control operations if the Sunnyvale facility were to become inoperable. Plans for CSOC included four mission control centers for an initial operational capability, which would later expand to eight for its full operational capability. CSOC was to also have its own system to communicate with the satellites.

The Sunnyvale facility of the Air Force's Space Division is responsible for developing and testing the operational readiness of a new computer system that is scheduled to replace the current system at Sunnyvale. In turn, this new system will be installed at CSOC's mission control centers where the Air Force Operational Testing Command will conduct additional operational tests. The Air Force planned for the new computer system to increase performance and reduce costs by replacing obsolete computers, centralizing real-time[1] data processing, simplifying operations at the tracking stations, and providing redesigned software to allow the mission controllers to use the system on a real-time basis.

Computer System Performance Not Operationally Demonstrated

In January 1987, the Air Force reported to the Congress that the computer system would be declared fully operational at Sunnyvale in September 1987. This system was scheduled to begin actual control operations at CSOC's first mission control center December 31, 1987. However, we found that none of the mission control centers at Sunnyvale or CSOC had completed initial operational testing, which involves testing the computer system, checking out procedures, certifying personnel, and integrating the communication system, as of October 1987. Operational testing of the new computer system for these mission control centers has taken longer than originally expected because of delays in developing the software, as well as software performance problems. If operational testing continues to identify system performance problems, additional modifications to the system may be needed, further delaying the operational start of the new system.

[1]Real-time computer applications control an ongoing process and deliver outputs not later than when needed for effective control.

Current Status of Operational Testing

Although the Air Force reported to the Congress[2] that under the current schedule the computer system would be declared fully operational in September 1987, the commander of the Sunnyvale facility stated that the system will have only completed full-scale development by this time. Further, the Sunnyvale commander stated that he will not declare the system fully operational until operational tests are completed and the system operators are fully confident of the performance and reliability of the new computer system. Although the commander did not provide an official estimate of when operational tests would be successfully completed for all the centers, he did explain that it may take up to 2 years before the new computer system is fully operational at all mission control centers. The commander further stated that the system currently supporting on-orbit satellites will be maintained to ensure adequate and safe support until the new computer system is operational. The Air Force originally planned to complete operational testing for all control centers by January 1987, before accepting the system.

For the computer system that would be installed in CSOC's first mission control center, a 1981 planning document showed that the Air Force planned to complete initial operational testing of that system at Sunnyvale by October 1984. This system was planned to have been installed and begin operations at CSOC in 1985. However, incomplete software and system performance problems have hampered testing for that computer system. Operational testing at Sunnyvale did not begin until February 1986, and was limited to versions of the system that were incomplete, according to a test report and Sunnyvale officials.

Whether the computer system will be ready for operations at Sunnyvale or CSOC by October 1988, the current estimate for having an operational mission control center at CSOC, will depend upon its performance test results. Although the computer system has been upgraded twice and capacity requirements have been reduced, the system still had difficulty in reliably maintaining contact with certain satellites, processing data simultaneously from the required number of satellites, and processing and displaying the greater amount of data that users are requesting from each satellite.

For example, in February 1987, the system was averaging only a 69.5 percent success rate in performing satellite contact functions, where 95 percent success is the minimum requirement. This average represented

[2]In January 1987, the Air Force reported this date to Congress in its supporting data for fiscal year 1988 budget estimates (program element 35110F).

test results from two different satellite systems that were scheduled to become operational at CSOC's first mission control center in December 1987. When supporting one satellite system the computer demonstrated an 84 percent success rate, but while supporting the other it demonstrated a 35 percent rate. Test reports listed the causes for the low success rate as inadequate design and other miscellaneous factors. Our examination of the detailed test results indicated that telemetry processing failures were a primary contributor to the inadequate success rates. In September 1987, the program manager told us that the satellite system with the lower success rate had been rescheduled to begin operations in October 1988. In response to our draft report, DOD reported in May 1988 that the average success rate for all satellite programs had increased to 90 percent. Although this figure would indicate a major improvement, it is still below the minimum requirement of 95 percent. In addition, we have not evaluated the comparability or accuracy of this new data.

With respect to system capacity, projections based on June 1986 system tests indicated that the system would require about five times the available computer capacity to process the work load. Problem areas in the system design included (1) underestimation of required input processing of raw telemetry data, (2) inadequate memory and file management, (3) operating system inefficiency, and (4) incompatibility between the computer's operating system and compiler. The Air Force and the contractor have made system changes, upgraded twice to larger computer systems, and improved the software performance.

But in March 1987, the projections of performance still indicated that the system would require more capacity than actually available (approximately 130 percent) on the enlarged computer. In October 1987, the Sunnyvale commander informed us that the projected capacity utilization had been reduced to 112 percent of available capacity and that the IBM system performance model predicted that capacity use could be reduced to 87 percent if further modifications were made to the display functions and the data base was changed to reflect current design specifications. As part of the agreement with IBM to upgrade the computer and its speed, the Air Force deleted the original requirement that the system use no more than 50 percent of the computer capacity when processing peak work loads and the program manager explained that it will now be accepted even if it uses 100 percent of its capacity to process the work load. The purpose of the original requirement was to accommodate growth in work load.

Upcoming Work Load May Require Additional Capacity and Performance

The upcoming work load includes the ability to process the amount of data users indicate they need to control satellites, the ability to support the currently planned satellite launch rate, and the ability for Colorado Springs to effectively continue satellite operations if Sunnyvale were to become inoperable. We believe that operational testing and other analyses, when completed, may show that additional performance is needed in order to effectively support upcoming satellite control operational needs.

Users are requesting that more data be processed than the system is designed to support. For example, based on June 1986 testing, users wanted the system to monitor up to several thousand measurements per second regarding a satellite's status. However, the computer system was designed to handle no more than 750 measurements per second and the planned system acceptance is based on this level. The original design specifications required 100 percent growth allowance above peak work loads to allow for increased user demands. As discussed earlier, the Air Force deleted this requirement from the system specification. According to Sunnyvale officials, users are attempting to reduce the amount of measurements to the 750 measurement per second design goal. Operational testing should provide more complete results on system performance in this area. Sunnyvale officials stated that the computer system under development may be able to provide for increased user demands if the system's capacity is increased and modified.

The Assistant Deputy Commander for Satellite Operations at Sunnyvale said that because of the current backlog of satellite launch missions, the Air Force plans to launch satellites at a faster rate over the next 3 years than originally planned. Operational testing should provide system performance data that will help the Air Force determine what launch rate the new system can support.

A 1980 Air Force report indicated that the Colorado Springs facility would be declared initially operational when it could support both its own satellite programs and high-priority satellite operations at Sunnyvale if that facility were to become inoperable. It was estimated that the Colorado Springs facility would need four control centers to support this capability. Colorado Springs would be declared fully operational when it expanded to eight centers and could support all critical satellite operations if Sunnyvale became inoperable. The Air Force now plans to complete the current development with two more capable mission control centers at the Colorado Springs facility. In addition, DOD has now taken the position, in response to our draft report, that although CSOC can

backup Sunnyvale with its existing two mission control centers, the requirement to do so no longer exists.

If the operational test results indicate that the computer systems at two Colorado Springs mission control centers do not provide sufficient performance and capacity to support users' work load needs, as well as backup Sunnyvale's satellite operations if that facility were to become inoperable, we believe alternative approaches may be needed. For example, Air Force and IBM officials identified such alternatives as replacing the existing computer with a larger one or moving some of the functions from the main computer to additional computer workstations. As of September 1987, contractual activities were underway to expand one of the CSOC mission control centers, to help support a planned launch rate surge in the 1988-1990 time frame caused by the space shuttle and expendable launch vehicle losses in 1986.

Air Force Had to Revise the Communication System for CSOC

Potential technical difficulties in communicating with the satellites have resulted in a revision of the plans for the communication system at CSOC. The revised system will not be as adaptable in meeting future needs and work load increases as the initially planned system, and it will not be operational until at least 1989. While the revised system is being constructed, the Air Force has established an interim system between the Colorado Springs and Sunnyvale facilities that will require Colorado Springs to use Sunnyvale's communication system to communicate with satellites. Air Force officials told us that if either the Sunnyvale facility or the interim communication system were to become inoperable, CSOC would have limited capacity to communicate with the satellites.

Revised Communication System Is Not Operational

In October 1985, the CSOC program office and DOD officials determined that the original method chosen for CSOC and its ground-based tracking stations to communicate with the satellites would not work effectively with existing DOD satellites. The original method was based on time division multiplexing,[3] in which data is transmitted and received at precisely defined time intervals. Because the DOD communications satellites were not designed to use this technique, several problems would have occurred. For example, the Air Force determined that when CSOC would communicate high volumes of data, the communications satellites would

[3]Multiplexing is a technique that makes more efficient use of a transmission facility by permitting multiple sources of communication to share that facility.

react as if they were being jammed and protectively point their antennae in another direction, prohibiting any communication. Also, the CSOC time division technique intermixed with normal satellite traffic could consume significant amounts of power of communications satellites, leaving less capacity for other uses of those satellites.

To address these problems, the Air Force dropped time division multiplexing and adopted frequency division multiplexing (which is currently used throughout the Air Force's Satellite Control Network). Frequency division multiplexing utilizes the communication bandwidth by dividing it into channels. According to CSOC program officials, this approach will not support the expected communications rates that could be supported if time division techniques were used. Using time division multiplexing, the Air Force expected to be able to communicate with the satellite at the rate of 5 million bits of data per second. Using frequency division multiplexing, however, the Air Force expects to be able to communicate with the satellite only at the rate of approximately 1 million bits of data per second. The Air Force expects the revised system to become operational in 1989. Although CSOC program office and Space Command officials expect this system to satisfy all current requirements, they expect that higher performance capabilities will eventually be needed.

Air Force Is Implementing an Interim Communication System

According to CSOC program officials, communication with satellites by CSOC, while the revised communication system is being built, will be routed through the Sunnyvale facility's communication system. CSOC will be dependent, therefore, on the Sunnyvale facility for wide-band communications until 1989, when the revised communication system is planned to become operational. To establish the communication connection between the two facilities, the Air Force is constructing an interim communication system, called the "wide-band backhaul line." Program officials said the interim communication system is already functional and is supporting system tests.

If either the Sunnyvale facility or the wide-band backhaul system were to become inoperable, CSOC would communicate with the satellites through a "narrow-band backup" communication system that has much less capability than the wide-band backhaul system, according to CSOC program officials. The narrow-band backup communication system has a data rate of 56,000 bits of data per second and less transmission quality than wide-band systems. CSOC's narrow-band system can provide a

backup capability for most of the assigned satellite operations, according to program officials, but one of the major satellite systems would have to rely primarily on other facilities for backup. If Sunnyvale were to become inoperable, CSOC program officials said that they do not know how well CSOC could support the operations of both facilities.

Furthermore, the Air Force has not yet approved an operational plan for conducting satellite control operations in the event of a failure of one of these satellite control centers. Air Force officials stated that backup operational plans will be in place in time to support the incremental activation of satellite control operations at CSOC.

Costs for Satellite Control Capabilities Have Increased

According to a December 1980 report, the Air Force expected to develop and implement new satellite control capabilities, including computer and communication systems, at a cost of $597 million. This estimate included $195 million for the new computer system to be used by the mission control centers at Sunnyvale, and $402 million for the new satellite control capability at four CSOC centers. However, through fiscal year 1987, the Air Force estimates it will have incurred costs of about $1.4 billion developing these new capabilities. These costs consist of $477 million for the new computer system at Sunnyvale and $904 million to develop and implement the operational capabilities at CSOC. The Air Force estimates indicate that an additional $449 million will be needed to complete these capabilities at CSOC and make the transition to operations.

Investment (research, development, test and evaluation, and procurement) in systems for satellite control operations will continue for those additional capabilities proposed in the short-term. In addition to the $449 million for CSOC, the Air Force currently estimates that approximately $1.8 billion will be needed for fiscal years 1987 through 1992 to continue modernizing satellite control systems.

Agency Comments and Our Evaluation

In the detailed comments attached to its May 1988 letter commenting on a draft of this report (see appendix II), DOD fully or partially concurred with the findings in this chapter. However, DOD felt that some clarification was needed in the problem areas of operational testing, system capacity, work load, cost, and performance.

DOD's letter requested that we clarify that CSOC operational testing involves procedure checkout, personnel certification, and communication system integration, in addition to testing of the computer hardware

and software (see appendix II). As a result, we revised the report to reflect this recommended change. DOD also provided updated information on the average success rate for contacting satellites (see appendix II). The report has been modified to include this updated information.

DOD's letter states that our report is not totally accurate in saying that the projections of performance indicate that the system at the Sunnyvale facility would require more capacity than actually available on the enlarged computer. We disagree. Since the data in our report was obtained, the Air Force, according to the Network Program Office director, has once again upgraded the computer hardware in some of the mission control centers, supporting our conclusion that the computer did not have sufficient capacity. In addition, even though the computer system architecture provides for increasing the size of the computer system, this type of increase may require the Air Force to incur additional cost. For example, according to the Air Force Network Program Office Director, no decision has been made yet as to whether the Air Force or the contractor will pay for the above computer hardware upgrade.

In its letter, DOD requests that we provide clarification regarding the capability of the current CSOC mission control centers to handle more work load than originally planned by supporting more than one satellite system (see appendix II). As a result, we revised the report to show that CSOC's mission control centers will have more capability than originally planned. We also revised the report to reflect DOD's position that CSOC currently has no requirement to backup Sunnyvale.

DOD's letter states that no rationale is provided that explains the 1980 estimate of $597 million to develop the new satellite control capabilities and the estimate of $1.4 billion spent through fiscal year 1987 (see appendix II). We disagree. The amount of each estimate that relates to developing CSOC and the new computer system at Sunnyvale is separately identified and explained in the report. In response to DOD's concern (see appendix II) that the $1.4 billion for CSOC and new computer system development through fiscal year 1987 was not just for computer and communication equipment development and implementation, we have clarified the report. These changes also clarify that the $449 million cost that is reported for CSOC to complete development and transition to operations is also for more than computer equipment development and implementation. Furthermore, we have also revised the report to show that the $1.8 billion estimate for modernizing satellite control systems through fiscal year 1992 is for more than just the satellite control systems at Sunnyvale.

DOD's letter states that it is unclear what "impeding development of new systems" means. We have revised the report to clarify that performance problems have impeded the development of the new systems to be installed in both CSOC and Sunnyvale. These performance problems have delayed the transition of these systems to an operational status at both locations. DOD's letter also states that it agrees that the new computer system problems have slowed the transition to an operational system at Sunnyvale and operational status at CSOC, but contends that this has not affected any operational space system. We agree that to date, there has been no adverse impact on the operational systems. However, it should be noted that there has been a less than expected work load because of the hold on shuttle launches since the Challenger accident and the reduction in expendable launch vehicle launches since the failures in 1986.

Substantial Technological Advances and Costs Forecasted for Long-Range Satellite Control System Architecture

The Air Force has developed a long-range architectural concept that, if implemented, will change the overall system network architecture for satellite control operations during the period 1990 through 2015. Successfully implementing this architecture will require the Air Force to achieve significant advances in computer and communication system technologies and performance. The Air Force has forecasted that it could cost about $48 billion (in fiscal year 1985 dollars) to develop, acquire, and implement the new more survivable architecture for military satellite control operations during this period. This forecast does not include the large number of satellites that would be needed if a strategic defense system were to be developed and deployed. The Commander of the Air Force Space Division stated that this architectural concept provides only a framework for future DOD space programs and that the cost estimating methodologies were intended to measure the relative merit of alternative architectures, rather than as an absolute basis for budgetary support.

Air Force Study Concluded Improved Survivability, Capacity, and Efficiency Are Needed

A 1987 Air Force satellite control architecture study concluded that future satellite control operations will require improved survivability as well as increased capacity and efficiency. It examined three alternative architectures that would provide improved capability.

The architecture study projects that approximately 135 satellites will be on-orbit by the year 2000, and 150 satellites will be on-orbit by the year 2015. However, these estimates do not include most of the nearly 10,000 satellites the study estimated might be needed to deploy the strategic defense system. The current system commands and controls approximately 55 active satellites.

As mentioned earlier in chapter 3, until operational testing of system performance is more complete, it is unclear how many satellites the Colorado Springs facility will be able to command and control. In addition, while CSOC would provide some level of operational continuity if Sunnyvale were to become inoperable, CSOC is also subject to destruction in the event of armed conflict. One official pointed out that the proposed, more survivable architecture would overcome this vulnerability by distributing ground control assets to mobile facilities. Finally, the Air Force found that the existing network is labor intensive, requiring over 4,000 government and contractor staff to maintain satellite control.

Air Force Plan Proposes Use of Complex Computer and Communication Technology

The Air Force plan proposes use of complex computer and communication technologies to change the satellite control architecture and operations in several ways. First, the new architecture would require more computer processing of both mission and control data on-board each satellite to reduce the current dependence on ground facilities, which according to the plan, are vulnerable and very labor intensive. Also, the Air Force plans to place ground control functions on mobile platforms with their own computer systems to improve survivability. Finally, the new architecture would implement space-based communications and tracking satellites that should reduce dependence on vulnerable ground, fixed-based, and labor-intensive tracking systems.

Significant advances in computer and communication technologies and performance must be achieved in order to implement the new architecture. An assessment of technical risks, prepared for the architecture study, indicates that the Air Force will have to overcome a number of complex technology issues concerning computer and communication system performance. For example, according to the assessment, significant advances in technology will be required to implement expert systems[1] capable of automatically performing satellite control operations, especially in the area of constructing decision-making software. There are also several technical uncertainties in the proposed development of survivable communications and tracking between satellites.

Costs for Long-Range Satellite Control Operations May Be Substantial

Investment and operations costs for satellite control operations will grow from present efforts to those additional capabilities proposed to provide a more survivable architecture.

The June 1987 version of the Air Force study[2] estimates that $57.44 billion (in fiscal year 1985 dollars) may be needed to develop, procure, and implement the new architecture for the period 1990 through 2015. This estimate includes $38.05 billion for research, development, and procurement, and $19.39 billion for operations and maintenance. This version of the study also estimates that the new architecture would

[1] An expert system is a computer program that performs at the level of a human expert in solving predefined problems in specific knowledge domains. For example, expert systems help doctors diagnose certain diseases.

[2] Satellite Control Architecture Systems Panel Report, The Aerospace Corporation, June 17, 1987. An earlier version of the study estimated that research, development, and procurement would cost approximately $65 billion and did not estimate either operations and maintenance cost or potential paybacks (savings). The Air Force used a different methodology for each of these two versions. We did not evaluate either methodology or the rationale for the revised cost estimate.

yield a $9.64 billion savings, bringing the net incremental cost of the architecture to $47.80 billion.

Air Force Space Division officials explained that the long-range architecture is extremely ambitious and that alternative acquisition strategies will be developed as they progress through the budget cycles. These officials stated that the long-range architecture is intended to provide a high-level concept to be used in Air Force space planning activities. The Commander of the Air Force Space Division stated that less costly approaches must be found to meet satellite control requirements.

As development in computer technology and communications for controlling satellites reaches into the next century, as costs continue to grow and as this country's defenses become more intertwined with this advancing technology, it becomes even more critical that decision makers have a high degree of confidence that projected capabilities can be met and are affordable. Accordingly, we believes it is important that the strategy for carrying out satellite control be given sufficient attention and visibility in order to help assure that a clear, cohesive, and comprehensive plan is developed, specifying long-range goals, objectives, capabilities, technical challenges, and the estimated cost to carry out Defense's satellite control mission.

Agency Comments and Our Evaluation

In the detailed comments attached to its May 1988 letter commenting on a draft of this report, DOD agreed with our analysis of a 1987 Air Force satellite control architecture study (see appendix II).

Congressional Request Letter

Congress of the United States
House of Representatives
Committee on Appropriations
Washington, DC 20515

September 8, 1986

Honorable Charles A. Bowsher
Comptroller General of the United States
General Accounting Office
Washington, D.C. 20548

Dear Mr. Bowsher:

In its report on DoD Appropriations for fiscal year 1987, the Committee expressed concern over the current development approach and acquisition strategy for the Consolidated Space Operations Center (CSOC), which consists of the Shuttle Operations and Planning Complex (SOPC) and the Satellite Operations Complex (SOC).

Please make the necessary arrangements for a review by GAO of current CSOC plans and supporting studies. Your review should address: costs and affordability; flexibility to accommodate future needs and policy options; technical risks; and, ability of "austere" SOPC and SOC to fulfill both defense and intelligence space mission needs.

The conclusions of this review will be used in our examination of DoD's fiscal year 1988 budget request. Consequently, please provide the results of GAO's work by April 3, 1987. Point of contact on the Committee's staff is Robert Seraphin, telephone 225-2847.

Sincerely,

Bill Chappell, Jr.
Chairman
Subcommittee on Defense

Agency Comments

DIRECTOR OF DEFENSE RESEARCH AND ENGINEERING

WASHINGTON, DC 20301-3010

(S&TNF)

17 MAY 1988

Mr. Frank C. Conahan
Assistant Comptroller General
National Security and International
Affairs Programs
U. S. General Accounting Office
Washington, DC 20548

Dear Mr. Conahan:

This is the Department of Defense (DoD) response to the General Accounting Office (GAO) draft report, "MILITARY SPACE OPERATIONS: Computer and Communication Systems For Shuttle and Satellite Operations," dated March 10, 1988 (GAO Code 510187/OSD Case 7556). For the most part the DoD concurs with the report.

The report does identify a number of deficiencies and concerns, however, that have since either been corrected or are no longer valid because of programmatic decisions. For example, the decision to cancel the Shuttle Operations and Planning Complex (SOPC) was not a direct result of the $29 million funding reduction in the FY 1987 budget, as the report states, but rather a combination of the Challenger accident, budget constraints, and the subsequent decision by the DoD to use expendable launch vehicles as the primary launch system. The draft report also implies that the Data System Modernization (DSM) development program is a part of the CSOC development. In actuality, the DSM is a separate development from the CSOC, and the CSOC is simply a user of the DSM product. The CSOC has not been the determining factor in the DSM development.

The discussion on costs throughout the report gives no explanation of the breakout of the $1.4 billion for the CSOC. It appears that the DSM costs have been included as part of the CSOC development cost. Therefore, additional clarification is necessary in these areas.

The detailed DoD responses to the report findings are provided in the enclosure.

Sincerely,

Robert C. Duncan

Enclosure

GAO DRAFT REPORT - DATED MARCH 9,1988
(GAO CODE 510187) OSD CASE 7556

"MILITARY SPACE OPERATIONS: COMPUTER AND COMMUNICATIONS SYSTEMS FOR SHUTTLE AND SATELLITE OPERATIONS"

DEPARTMENT OF DEFENSE COMMENTS

* * * * *

FINDINGS

- FINDING A: The Consolidated Space Operations Center (CSOC). The GAO reported that, in 1980, Defense decided to improve overall satellite control by developing an additional satellite control facility at a new Consolidated Space Operations Center (CSOC) located at Falcon Air Force Station near Colorado Springs, Colorado. The CSOC was originally designed to control both military satellites and military space shuttle missions; however, funding for the shuttle complex was not included in the FY 1988 budget and the contract to develop its data processing system was terminated at the end of FY 1987. The GAO observed, therefore, that the primary CSOC responsibility will be the command and control of military satellites. (The GAO noted that, currently, the primary Air Force satellite operations facility is located in Sunnyvale, California and, originally, Sunnyvale and CSOC were to function as mutual backup systems to command and control DoD satellite in the event of failure of either facility.) The GAO found that, since 1981, the DoD has spent about $1.4 billion to develop a new CSOC, including its computer and communication capabilities, and to upgrade the capabilities of the existing satellite control facility. The GAO further found that the DoD estimates it will spend about $477 million to develop and acquire the new computer system for the Sunnyvale facility, approximately $904 million on CSOC through FY 1987, and $449 million thereafter, to completely develop and implement the capabilities at the CSOC facility. In response to congressional concerns, the GAO issued two reports on the CSOC program in 1982 and 1983, which indicated concerns with the CSOC program. (The 1982 report is OSD case 5852. No record can be found of the 1983 case.) As an example, in the 1983 report the GAO stated that the original DoD justifications for the shuttle complex were questionable. In the 1982 report, the GAO found,

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in part, that the CSOC development program could be subject to cost overruns. The GAO observed that the schedule estimates for a fully operational facility at the planned CSOC and planned upgrades to the existing satellite control center at Sunnyvale have, in fact, been more optimistic than events have borne out. (pp. 4-5, pp. 15-18/GAO Draft Report)

DoD Comment: Partially Concur. The GAO states that the $1.4 billion cost for development of the CSOC includes the full cost of DSM development. This should not be included as a CSOC cost since it was a separate development. The CSOC is simply a user of the DSM hardware and software.

- FINDING B: Shuttle Complex Has Been Cancelled. The GAO noted that, in 1979, the DoD justified the development of an independent military shuttle complex based on the need to correct several deficiencies in its ability to plan and execute space shuttle flights at the National Aeronautics and Space Administration (NASA) Johnson Space Center. The GAO also noted that, according to the DoD, its own complex was needed to eliminate complete reliance on the Johnson Space Center, increase flight rate capacity, increase security, and provide complete Defense control over its missions. The GAO observed that to be independent of the Johnson Space Center, the computer system for an independent DoD shuttle complex would need to perform three key functions: flight planning, flight readiness, and flight control. The GAO noted that these functions currently are conducted at the Johnson Space Center, using numerous computers and over eight million lines of software code. The GAO noted that the DoD planned to replicate over 90 percent of this software for use at its shuttle complex. Despite these original plans for a full shuttle complex at Colorado Springs, which would match the capabilities of the Johnson Space Center, the GAO found that while preparing its FY 1987 budget, the Air Force eliminated funding for the shuttle complex on the grounds that the estimate $600 million cost would be too high. The GAO further found that, later, the DoD reinstated funding for a limited, "austere" shuttle complex; however, in November 1986, prompted by a $29 million congressional budget reduction for the CSOC as a whole, all funding for the shuttle complex was eliminated. The GAO concluded that the austere

shuttle complex, even if its funding had continued, would not have satisfied the original requirements justifying an independent military shuttle complex. While it would have provided some improvement, the GAO observed it would not have eliminated the reliance on the Johnson Space Center for some critical functions--likewise, it would not have increased overall flight rate capacity, eliminated all critical constraints for conducting missions above the secret security level, or provided Defense with complete operational control over its shuttle missions. (pp. 6-7, pp. 22-25, pp. 27-29/GAO Draft Report)

DoD Comment: Partially Concur. The GAO reported that, in November 1986, prompted by a $29 million congressional budget reduction for the CSOC as a whole, the DoD eliminated all funding for the SOPC. In actuality, the reason for the cancellation of the SOPC was the Challenger accident, the constrained DoD budget, and the subsequent DoD decision to use expendable launch vehicles as the primary launch system. In order to support the overall Space Launch Recovery Program, the SOPC was identified as one of several important programs that the DoD budget could no longr afford. Due to schedule delays and performance degradation of the shuttle, the DoD effected programmatic decisions in the summer/fall of 1986 that led to the off-loading of most critical national security payloads from the shuttle to expendable launch vehicles. This also negated the need for a separate military shuttle complex and helped to relieve future DoD shuttle-related capacity problems at Johnson Space Center.

- FINDING C: Johnson Space Center Projects It Can Support Currently Planned DoD Mission Requirements. While noting that the Johnson Space Center could not support the number of shuttle flights planned by the NASA and the DoD prior to the Challenger accident, the GAO found that the Center has reported it can support the reduced flight rate currently projected through the early 1990s. The GAO noted that since the accident, the DoD has shifted many of its missions to expendable launch vehicles and, in addition, the Johnson Space Center is also considering changes in the design of its computer systems that would allow it to increase its mission capacity. The GAO found that the Johnson Space Center support to the DoD would be

provided with the current Center computer systems and previously planned upgrades. As an example, the GAO noted that, according to Center officials, flight software production and ascent/descent flight-design systems currently can support up to five secure flights annually. While this capacity allows the Center to support all approved and projected military flights through 1991, upgrades to both systems are necessary to support the six military flights per year projected for 1992-1994. The GAO noted that, according to these same officials, the upgrades can be completed by 1990 and will make it possible to support a military flight rate of at least 10 per year. The GAO further found that Johnson Space Center officials are studying alternative architectures for the computer system supporting shuttle mission operations. The GAO concluded that it appears the Johnson Space Center can support all currently planned DoD missions through the early 1990s. (pp. 25- 27/GAO Draft Report)

DoD Comment: Concur.

- FINDING D: DoD Space Requirements May Change. The GAO reported that the most recent DoD space policy, dated February 1987, provides direction to actively explore the potential use of military man-in-space. The GAO further reported that the DoD Authorization Act for FY 1988 and FY 1989, approved December 4, 1987, directs the Secretary of Defense to study the need for a centralized facility to conduct both manned and unmanned space operations. The GAO observed that DoD briefings addressing this recent space policy indicated that the DoD may identify a long-term need for complex and highly classified missions, involving not only the shuttle but other future space vehicles. The GAO concluded that it is unclear whether this need may justify a shuttle complex at the CSOC. The GAO further concluded that since the CSOC shuttle systems were to have essentially replicated Johnson Space Center Systems, and these were not designed to support such complex missions, the DoD will likely consider other system design alternatives if a future determination is made that a separate CSOC shuttle complex is needed. (pp. 29-30/GAO Draft Report)

DoD Comment: Concur.

- **FINDING E: Current Status Of Operational Testing.** The GAO reported that, in 1980, the Air Force issued a plan to improve the overall satellite control network, which would involve development of an additional satellite control network, which would involve development of an additional satellite control facility at CSOC. The GAO further reported that the Air Force Pace Division Sunnyvale facility is responsible for developing and testing the operational readiness of a new computer system, which is scheduled to replace the current system at Sunnyvale--in turn, this new system will be installed at the CSOC mission control centers where the Air Force Operational Testing Command will conduct additional operational tests. While in January 1987, the Air Force reported to the Congress that the computer system would be declared fully operational at Sunnyvale in September 1987, the GAO found that none of the mission control centers at Sunnyvale or the CSOC had completed initial operational testing of the computer system as of October 1987. Collection of initial operational test data and a report on that data for the Sunnyvale first mission control center is expected to be completed in February 1988. The GAO observed that the Air Force had originally planned to complete operational testing for all control centers by January 1987, before accepting the system. The GAO concluded that whether the computer system will be ready for operations at Sunnyvale or the CSOC by February 1988, will depend upon its performance and test results. The GAO found that, although the computer system had been upgraded twice and capacity requirements have been reduced, the system still had difficulty in reliably maintaining contact with certain satellites. The GAO noted, for example, that in February 1987, the system was averaging only a 69.5 percent success rate in performing satellite contact functions, where 95 percent success is the minimum requirements.

  DoD Comment: Concur. Clarification is necessary, however, in two specific areas. First, testing at the Consolidated Space Test Center (CSTC) (formerly the Satellite Control Facility) and the Consolidated Space Operations Center involves not only DSM hardware and software, as the GAO indicates, but also procedure checkout, personnel certification, and communication

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system integration. All must be fully tested prior to operational turnover.

Second, the February 1987 success rate of 69.5 percent, that the GAO quoted, was accurate at the time of the GAO field work, but has since been raised to an average success rate of approximately 90 percent across all DSM contacts at the CSOC and the CSTC. This is a direct result of performing the standard debugging of any new hardware, software, and communication gear, and normal tuning. These efforts are continuing, leading to satisfying the planned success rate requirement of 95 percent .

- FINDING F: System Capacity. With respect to system capacity, the GAO found that projections, based on June 1986 system tests, indicate the system would require about five times the available computer capacity to process the work load. While the Air Force and the contractor have made system changes, upgraded twice to larger computer systems, and improved the software performance, in March 1987, the projections of performance still indicated that the system would require more capacity than actually available (approximately 130 percent) on the enlarged computer. The GAO observed that, as part of the agreement with IBM to upgrade the computer and its speed, the Air Force deleted the original requirement that the system use no more than 50 percent of the computer capacity when processing peak work loads. According to the GAO, the program manager explained that it will now be accepted even if it uses 100 percent of its capacity to process the work load. The GAO observed that the purpose of the original requirement was to accommodate growth in work load. The GAO concluded that the Air Force capability to plan and control satellite operations will depend, upon among other factors, on the performance of its new computer and communication system. (pp. 31-38/GAO Draft Report)

DoD Comment: Partially Concur. The GAO statement that the projections of performance indicate that the system at the CSTC would require more capacity than actually available on the enlarged computer is not totally accurate. The Data System Modernization (DSM) system contract, awarded in December 1980, was originally sized at approximately 0.8 million lines of unique software, 4+ years of development, and 2+ years

for operational transition. Design reviews with users led to new requirements, with engineering change proposals and redesigns resulting. The schedule was compressed to accommodate this growth, resulting in development overlapping with operational transition. The software size had doubled by the close out of the DSM development contract in December 1987. The ability of DSM to handle large amounts of data via its modular software is directly related to the speed of its processors, its I/O channels, and storage devices. DSM is based on the commercial IBM 370 architecture, which is noted for its continuing improved computer and peripheral performance capability. DSM has taken advantage of this by providing computers and peripherals sized to carry the load expected to be encountered in each Mission Control Complex (MCC). In some cases, where the initial choices proved to be inadequate to meet processing needs in a MCC, faster processors with more storage were quickly installed to improve capacity with no negative impact on reliability or software function. Problems with processor loading, data errors and user procedures have been encountered and have been or are being resolved. Efforts are underway with the operational users to provide acceptable, reliable support for all satellites. Based on progress to date, there appears to be no reason that the transition to the DSM cannot successfully meet current and future operational requirements.

- FINDING G: Upcoming Work Load May Require Additional Capacity And Performance. The GAO reported that the upcoming work load includes the ability to process the amount of data users indicate they need to control satellites, the ability to support the currently planned satellite launch rate, and the ability for Colorado Springs to effectively continue satellite operations if Sunnyvale were to become inoperable. The GAO found that users are requesting more data be processed than the system is designed to support. As an example, the GAO cited that, based on June 1986 testing, users wanted the system to monitor up to several thousand measurements per second regarding a satellite status; however, the computer system was designed to handle no more than 750 measurements per second and the planned system acceptance is based on this level. The GAO further noted that, according to the Assistant Deputy Commander for Satellite Operations at Sunnyvale, because of the current

backlog of satellite launch missions, the Air Force plans to launch satellite at a faster rate over the next three years than originally planned. A 1980 Air Force report indicated that the Colorado Springs facility would be declared initially operational when it could support both its own satellite programs and high-priority satellite operations at Sunnyvale, if that facility were to become inoperable--and it was estimated that the Colorado Springs facility would need four control centers to support this capacity. The GAO found, however, that currently, only two mission control centers are planned for Colorado Springs. If the operational test results indicate that the computer systems at Colorado Springs missions control centers do not provide sufficient performance and capacity to support work load needs of users, as well as backup the Sunnyvale satellite operations (if that facility were to become operational), the GAO concluded that alternative approaches may be needed. As an example, the GAO noted that Air Force and IBM officials identified such alternatives as replacing the existing computer with a larger one or moving some of the functions from the main computer to additional computer workstations. The GAO further concluded that supporting the expected work load may require more capacity than the computer offers. (pp. 39-41/GAO Draft Report)

DoD Comment: Partially Concur. The GAO statement that only two mission control centers are planned at the CSOC and that a 1981 Air Force report identified the need for four MCCs at the CSOC is accurate. However, this point requires further clarification. The CSOC can backup the CSTC with its existing MCCs. Although the CSOC has only two MCCs, these are multi-function MCCs, thereby supporting several systems (i.e. MCC-IA supports GPS, MCC-IB supports DSP and DMSP, MCC-II supports DSCS, FLTSATCOM, NATO II/III). Since the Shuttle MCC (SOPC) was cancelled, there is no requirement, nor intention, to backup the Shuttle MCC at the CSTC. Neither is there a current requirement for the CSOC Satellite Operations Complex (SOC) to provide a backup to the CSTC; however, there is a capability for the CSTC to provide backup to the CSOC SOC. Therefore, the 1981 report need for four MCCs is no longer accurate. (The response to the GAO finding regarding the ability to upgrade is included under DoD Comment to Finding F.)

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- FINDING H: Air Force Had To Revise The Communication System For The CSOC. The GAO found that the Air Force had to revise its initially-planned CSOC communication link to the satellite to overcome technical problems. The GAO reported that the original method was based on time division multiplexing and because the DoD communications satellites were not designed to use this technique, several problems would have occurred. Accordingly, the Air Force dropped time division multiplexing and adopted frequency division multiplexing. The GAO found, however, using frequency division multiplexing will provide about 1 million bits of data per second versus 5 million bits of data per second, as originally planned. The GAO noted that, while the CSOC program office and Space Command officials expect this system to satisfy all current requirements, they expect that higher performance capacities will eventually be needed. The GAO also found that, while the revised system is being constructed, the Air Force has established an interim system between the Colorado Springs and Sunnyvale facilities that will require Colorado Springs to use the Sunnyvale communication system to communicate with satellites. The GAO noted that, according to Air Force officials, if either the Sunnyvale facility or the interim communication system were to become inoperative, the CSOC would have limited capacity to communicate with the satellites. The GAO concluded that the revised system will not be as capable of meeting future needs and work load increases as the initially planned system, and it will not be operational until at least 1989. (pp. 41-44/GAO Draft Report)

  DoD Comment: Concur. The GAO is correct that the communication system will not be as capable of meeting potential future needs as the initially planned system. It does, however, meet all current firm requirements. Severe fiscal constraints prevent any attempt to accommodate non-validated needs in the current system. When future needs are validated, they will be accommodated.

- FINDING I: Costs For Satellite Control Capabilities Have Increased. The GAO noted that, according to a December 1980 report, the Air Force expected to develop and implement the new computer and

communication capabilities at a cost of $597 million. The GAO found, however, that through FY 1987, the Air Force will have spent approximately $1.4 billion; and the transition to operations will cost $449 million more. The GAO further found that the Air Force plans to spend an additional $1.8 billion through FY 1992, to continue modernizing satellite control systems at Sunnyvale and is further updating its estimates for other activities. The GAO observed that performance problems identified throughout testing have impeded the development of these new systems. The GAO concluded that the Air Force cost estimates have been more optimistic than events have borne out. (pp. 45-58/GAO Draft Report)

DoD Comment: Partially Concur. The GAO found that, through FY 1987, the Air Force will have spent approximately $1.4 billion on the development of the new computer and communications capability, as opposed to the expected cost of $597 million. No rationale is provided that explains these costs. The $1.4 billion cost includes both the full CSOC development (including military construction) and full DSM development. This is not just computer and communication equipment development and implementation, as implied by the GAO finding. Likewise, the transition cost, referenced at $449 million, is undefined since the CSOC development continues through FY 1990. It is also unclear what "impeding development of new systems" means. The DSM problems have slowed the transition to an operational DSM system at the CSTC, and slowed transition to operational status at the CSOC, but this has not impacted any operational space system. Additionally, the $1.8 billion that the GAO states the Air Force is planning to spend through FY 1992 for modernizing satellite control systems at Sunnyvale is not completely accurate. The modernization at Sunnyvale is but one of the facets of the overall modernization included under the Air Force satellite control architecture plan.

- **FINDING J: Air Force Study Concluded Improved Survivability, Capability, And Efficiency Are Needed.** The GAO reported that a 1987 Air Force satellite control architecture study concluded that future satellite control operations will require improved survivability as well as increased capacity and

efficiency, and projected 150 satellites on-orbit by 2015--not including nearly 10,000 that may be needed for a Strategic Defense System. The GAO observed that the current system only commands and controls approximately 55 active satellites. The GAO concluded that, until operational testing of system performance is more complete, it is unclear how many satellites the Colorado Springs facility will be able to command and control. The GAO also pointed out that, while the CSOC would provide some level of operational continuity if Sunnyvale were to become inoperable, the CSOC is also subject to destruction in the event of armed conflict. The GAO noted that, according to one official, the proposed, more survivable architecture would overcome this vulnerability by distributing ground control assets to mobile facilities. (p. 10, pp. 47-48/GAO Draft Report)

DoD Comment: Concur.

- FINDING K: Air Force Plan Proposes Use Of Complex Computer And Communication Technology. The GAO reported that the Air Force plan proposes use of complex computer and communication technologies to change the satellite control architecture and operations in several ways, as follows:

  - the new architecture would require more computer processing of both mission and control data on-board each satellite to reduce the current dependence on ground facilities, which (according to the plan) are vulnerable and very labor intensive;

  - the Air Force plans to place ground control functions on mobile platforms with their own computer systems to improve survivability; and

  - the new architecture would implement space-based communications and tracking satellites that should reduce dependence on vulnerable ground, fixed-based, and labor-intensive tracking systems.

  The GAO found that significant advances in computer and communications technologies and performance must be achieved in order to implement the new architecture. In this regard, the GAO noted that an assessment of technical risks prepared for the architecture study indicates that the Air Force will

have to overcome a number of complex technology issues concerning computer and communication system performance. The GAO further observed that there are also several technical uncertainties in the proposed development of survivable communications and tracking between satellites. The GAO concluded that successfully implementing the new architecture will require the Air Force to achieve significant advances in computer and communication system technologies and performance. (p. 46, pp. 48-49/GAO Draft Report)

DoD Comment: Concur.

- FINDING L: Costs For Long-Range Satellite Control Operations May Be Substantial. The GAO reported that investment and operations costs for satellite control operations will grow from present efforts to those additional capabilities proposed to provide a more survivable architecture. The GAO found that the June 1987 versions of the Air Force study estimates that $57.44 billion (in FY 1985 dollars) may be needed to develop, procure, and implement the new architecture for the period 1990 through 2015. The GAO observed that this version of the study also estimates that the new architecture would yield a $9.64 billion savings, bringing the net incremental cost of the architecture to $47.80 billion. The GAO noted that Air Force officials explained that the long-range architecture is extremely ambitions and that alternative acquisition strategies will be developed as they progress through the budget cycles. The GAO further noted that, according to these officials, the long-range architecture is intended to provide a high-level concept to be used in Air Force space planning activities. The GAO concluded that, as development in computer technology and communications for controlling satellites moves into the next century, as costs continue to grow, and as the defenses of the country become more intertwined with this advancing technology, it becomes even more critical that decision makers have a high degree of confidence that projected capabilities can be met and are affordable. Accordingly, the GAO further concluded that it is important that the strategy for carrying out satellite control be given sufficient attention and visibility in order to help ensure that a clear, cohesive, and comprehensive plan is developed, specifying long-range goals, objectives, capabilities, technical challenges, and the estimated cost to carry out the Defense

satellite control mission. (p. 11, pp. 49-50/GAO Draft Report)

DoD Comment: Concur.

RECOMMENDATIONS

- NONE:

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*U.S. G.P.O. 1988-201-749:80213